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## Space Weather Technical Forecast

Issued on Sunday, 11 February 2024 at 01:23 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales <https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales>

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**Space Weather Forecast Headline: Current S1 conditions likely declining. Further R1-R2 Radio Blackouts Likely. Chance of G1/G2 conditions days 2 and 3 (12-13 Feb).**

### Analysis of Space Weather Activity over past 24 hours

**Solar Activity:** Solar activity recorded at GOES16 has been High over the past 24 hours, with a peak M9 flare, observed at 10/2307 UTC, originating from AR3576, which is located in the southwest quadrant. This produced an R2 Radio Blackout, with coronal dimming evident in SDO/AIA 211 imagery, which potentially signals a CME lift-off, currently awaiting imagery for analysis of any potential Earth-directed component.

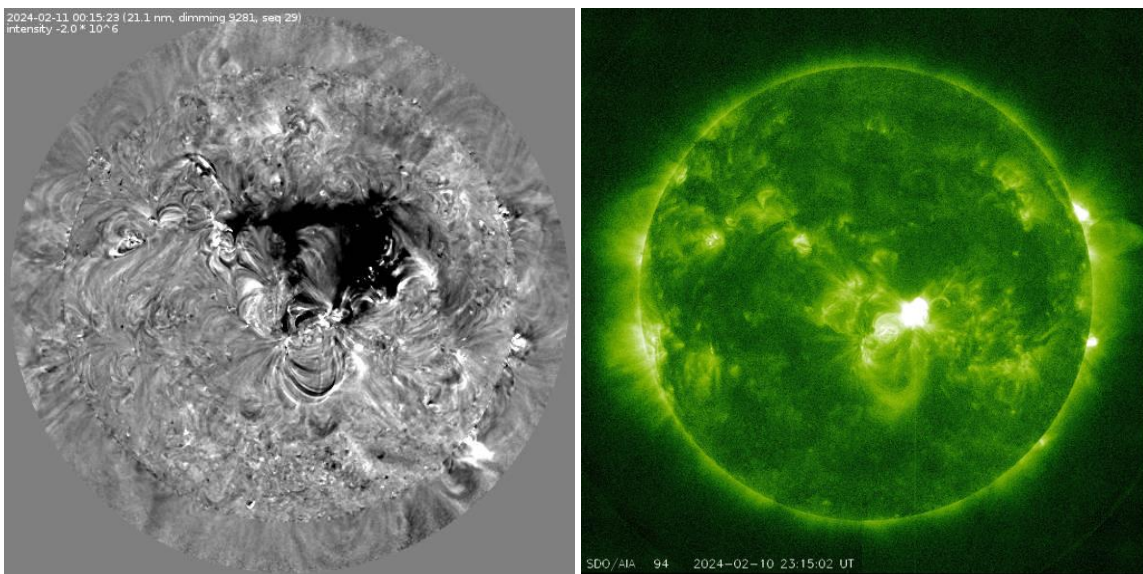


**Figure 0: SDO/AIA 211 imagery (left) shows dimming in association with the M9 flare, originating from AR3576, as seen in SDO/AIA 94 (right). Awaiting coronal graph imagery for potential CME from this event.**

There are currently eight sunspot regions on the visible disc. AR3576 remains the dominant spot in terms of complexity and size. There continues to be slight growth in the penumbra of the largest spot, especially on its northern periphery. One of the intermediate delta regions has now faded, as the large central spot has fragmented, but there remains at least two other small delta regions. AR3582 is the next most complex sunspot, which has continued to show minor growth in its intermediate spots, which will continue to be monitored for any further development in its growth and magnetic complexity. All other spots are relatively simple and unremarkable. AR3580 has faded to plage.

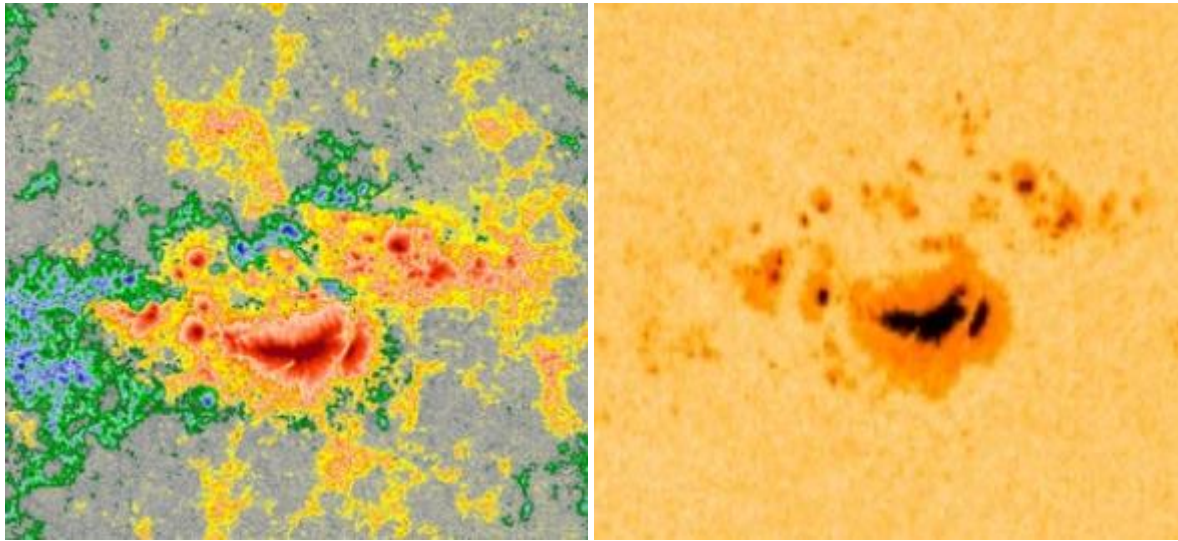


**Figure 1: HMI-magnetogram (left) and intensitygram (right) show the large and magnetic complexity of AR3576 located in the southwest quadrant, near centre-disc.**

One potentially Earth-directed CME was observed in the past 24 hours from within the vicinity of AR3576. This was associated with a C8 flare and a filament disturbance, which produced a CME at around 10/0700 UTC. This has been analysed and is considered to be Earth-directed, arriving at Earth late on day 2 (12 Feb) or early day 3 (13 Feb). No other Earth-directed CMEs have been observed, pending any CME from the recent M9 flare.

**Solar Wind / Geomagnetic Activity:** Solar winds, as measured by ACE and DSCOVR at L1, started the period at slightly elevated levels, near 450km/s, possibly due to a weak CME arrival, before a steady decline back to slow-ambient levels, currently near 350km/s. Solar wind density started the period average to above average, with a peak of 14ppcc at 10/0600 UTC, before declining to below average values by the end of the period. The IMF (Bt) has been generally weak throughout, peaking at 6nT. The north-south component (Bz) varying weakly between -4 and +4nT, with a brief southward orientation between 10/0800 UTC and 10/1200 UTC, possibly due to a weak transient feature. The Phi angle varied at the start of the period, then became mostly negative (towards the Sun) from 10/0735 UTC. Geomagnetic activity has been Quiet (Kp0-2) throughout.

**Energetic Particles / Solar Radiation:** GOES18 high energy (greater than 10MeV) proton flux remains above the S1 (10pfu) threshold, with a peak value of 187pfu observed at 10/1240 UTC, and shows a steady declining trend.

GOES16 high energy (greater than 2MeV) electron flux remained at Normal Background levels. The associated 24-hour fluence was well below the Active (1e8 integrated pfu) threshold and has had a flat trend, with the 11/0001UTC fluence value of 1.79e6 pfu observed.

#### **Four-Day Space Weather Forecast Summary**

**Solar Activity:** Moderate X-ray flare activity likely, and a slight chance of further X-class activity, with AR3576 providing the vast majority of the risk as Ex-AR3575 continues to rotate further onto the far side of the disk.

**Solar Wind / Geomagnetic Activity:** There are currently three potential CMEs that feature in the forecast, which may enhance the solar wind environment. The first is a glancing blow CME from 08 Feb, which is likely to arrive around 12/1200UTC. The second is associated with the

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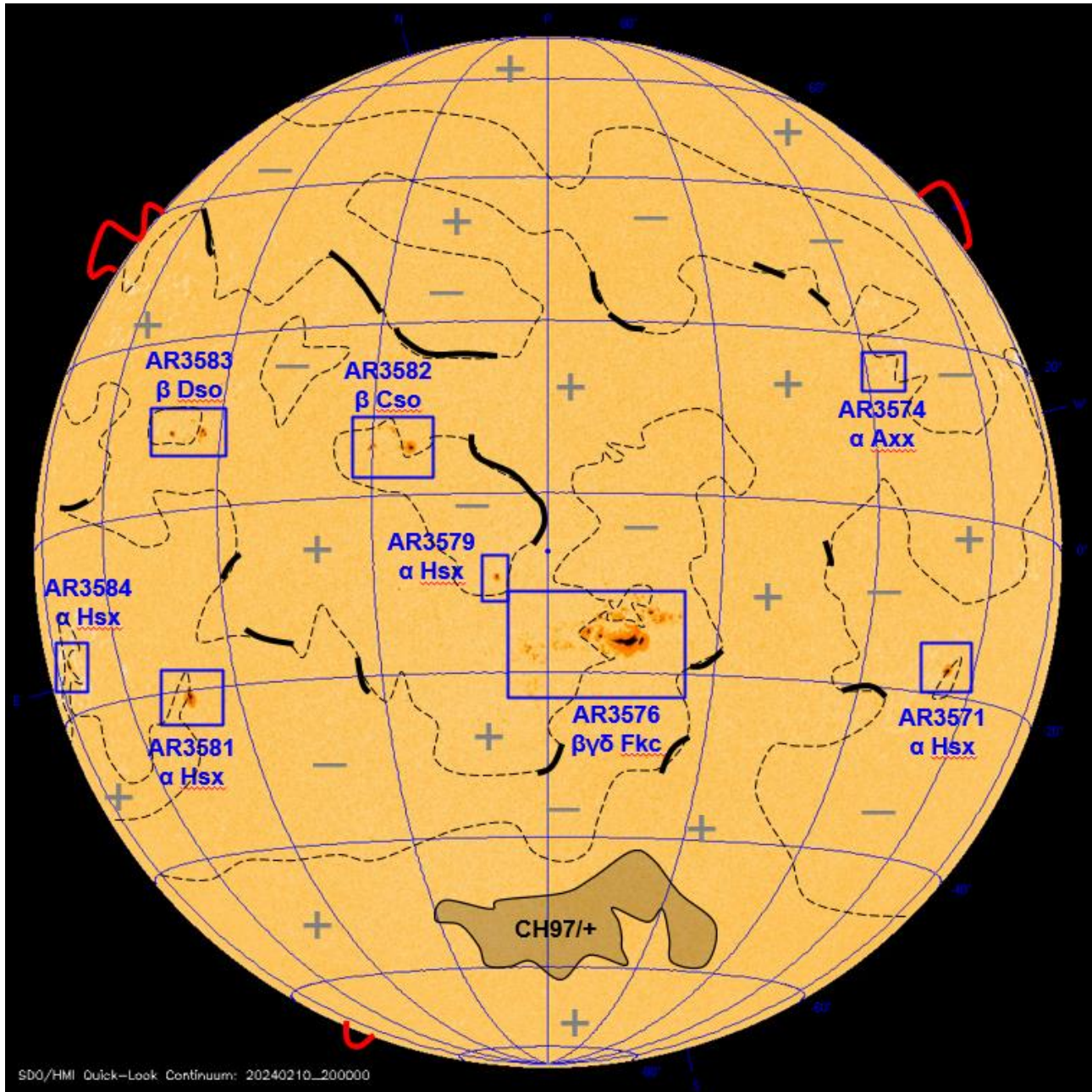
potential shock effects from the large CME associated with the X3.3 event, perhaps with the chance of a shock arrival between 11/0900-12/2359 UTC. Finally, there was an eruption near south-centre disc on 10 Feb, with possible arrival time of either late on day 2 (12 Feb) or into day 3 (13 Feb), before effects wane by day 4 (14 Feb). The recent M9 flare may produce a potential Earth-directed CME, although pending any analysis, once imagery becomes available. There is currently one coronal hole on the disc, CH97/+, located in the southern hemisphere, which is not expected to give us any enhancements.

Geomagnetic activity should be mostly Quiet on day 1 (11 Feb). The shock from the X3.3 flare brings a slight chance of G1 conditions on day 1 (11 Feb), although this is considered low confidence, with this becoming a chance of G1/G2 on day 2 (12 Feb) and an outside slight chance of a G3 should all three possible CMEs arrive in quick succession. Lingering CME effects are possible by day 3 (13 Feb), though overall geomagnetic activity should fall back to Quiet to Unsettled by day 4 (14 Feb) with a chance of Active.

**Energetic Particles / Solar Radiation:** GOES18 high energy (greater than 10MeV) proton flux is currently at S1 levels following the X3.3 flare on 09 Feb. The high energy proton flux should begin to subside through the period, though likely remaining above S1 through day 1 (11 Feb), with a gradual fall to below S1 levels possibly by day 2 (12 Feb).

High energy electron flux (greater than 2MeV) is expected to continue at current Normal Background levels, with the associated 24-hour electron fluence remaining well below the Active threshold.

Figure 2. Solar Analysis Valid 10/2000 UTC.



**Key:** Filament — , Prominence — , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

## Geomagnetic Storms:

There are up to three CMEs which currently feature in the forecast.

The first is a CME associated with the 08/2030 UTC south-centre filament eruption. This is modelled as crossing 1AU, mainly behind and below the Sun-Earth line on day 2 (12 Feb) around midday.

The second is associated with the potential shock effects from the large CME associated with the X3.3 event. Despite the position of this event around the southwest limb, given the size of the eruption and position of the parker spiral some shock enhancement may be possible either on day 1 (11 Feb) or possibly day 2 (12 Feb). Finally there was an eruption near south-centre disk associated with a potential filament disturbance and long period high-level C-class flare around 0700 on 10 Feb. This has been analysed as Earth-directed, possibly arriving late on day 2 (12 Feb) or into day 3 (13 Feb).

However, a recent M9 flare late on 10 Feb, originating from AR3576, may produce another potentially Earth-directed CME, although currently awaiting coronagraph imagery for confirmation. No coronal hole fast wind enhancements are expected within the forecast period, therefore the background solar winds should remain similar with a chance of rising to slightly elevated at times.

Quiet to Unsettled conditions are expected to start the four-day period. The shock from the X3.3 flare brings a slight chance of G1 conditions on day 1 (11 Feb), with this becoming a chance of G1/G2 late on day 2 (12 Feb) or into day 3 (13 Feb) and an outside chance of a G3 should all three possible CMEs arrive in quick succession. Lingering CME effects are possible by day 4 (14 Feb), though overall geomagnetic activity should fall back to Quiet to Unsettled.

| Geo-Magnetic Storm       | Level    | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) | Day 2 (00-24 UTC) | Day 3 (00-24 UTC) | Day 4 (00-24 UTC) |
|--------------------------|----------|------------------------|-------------------|-------------------|-------------------|-------------------|
| Probability (Exceedance) |          |                        | (%)               | (%)               | (%)               | (%)               |
| Minor or Moderate        | G1 to G2 | No                     | 10                | 50                | 40                | 10                |
| Strong                   | G3       | No                     | 1                 | 5                 | 2                 | 1                 |
| Severe                   | G4       | No                     | 1                 | 1                 | 1                 | 1                 |
| Extreme                  | G5       | No                     | 1                 | 1                 | 1                 | 1                 |

## Geomagnetic Activity - Earthbound Coronal Mass Ejections

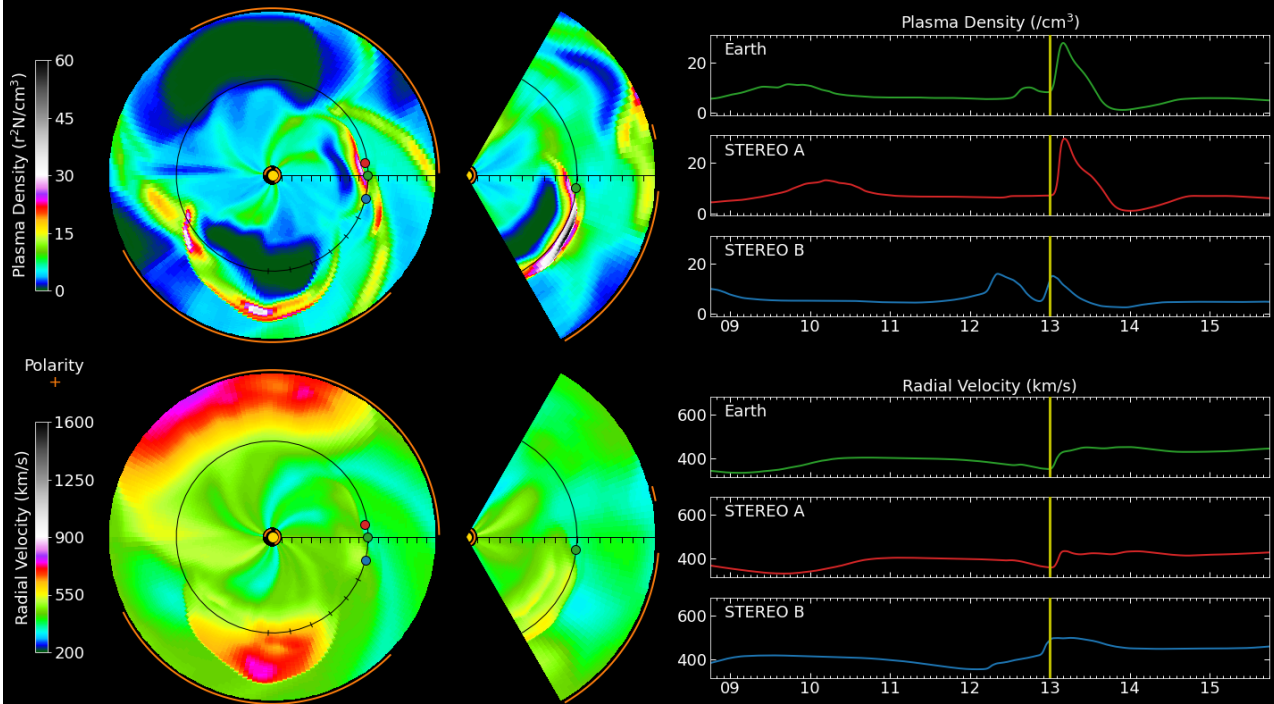
| Date/time 21.5R (UTC) | Halo: Full or Partial | Source            | Source Location | Estimated Speed | Estimated Arrival Time | Comments      |
|-----------------------|-----------------------|-------------------|-----------------|-----------------|------------------------|---------------|
| 08/2030               | Partial               | Filament Eruption | S centre        | 641 km/s        | 12/1200 UTC            | Glancing Blow |
| 09/1507               | Partial               | X3.3              | Around W limb   | 2222 km/s       | 11/0900-12/2359        | Shock         |
| 10/1058               | Partial               | Filament lift-off | S centre        | 930 km/s        | 12/2200                | Direct-hit    |

**Figure 3: MOSWOS ENLIL and Ensemble – shows potential CME arrivals on 12 and 13 Feb.**

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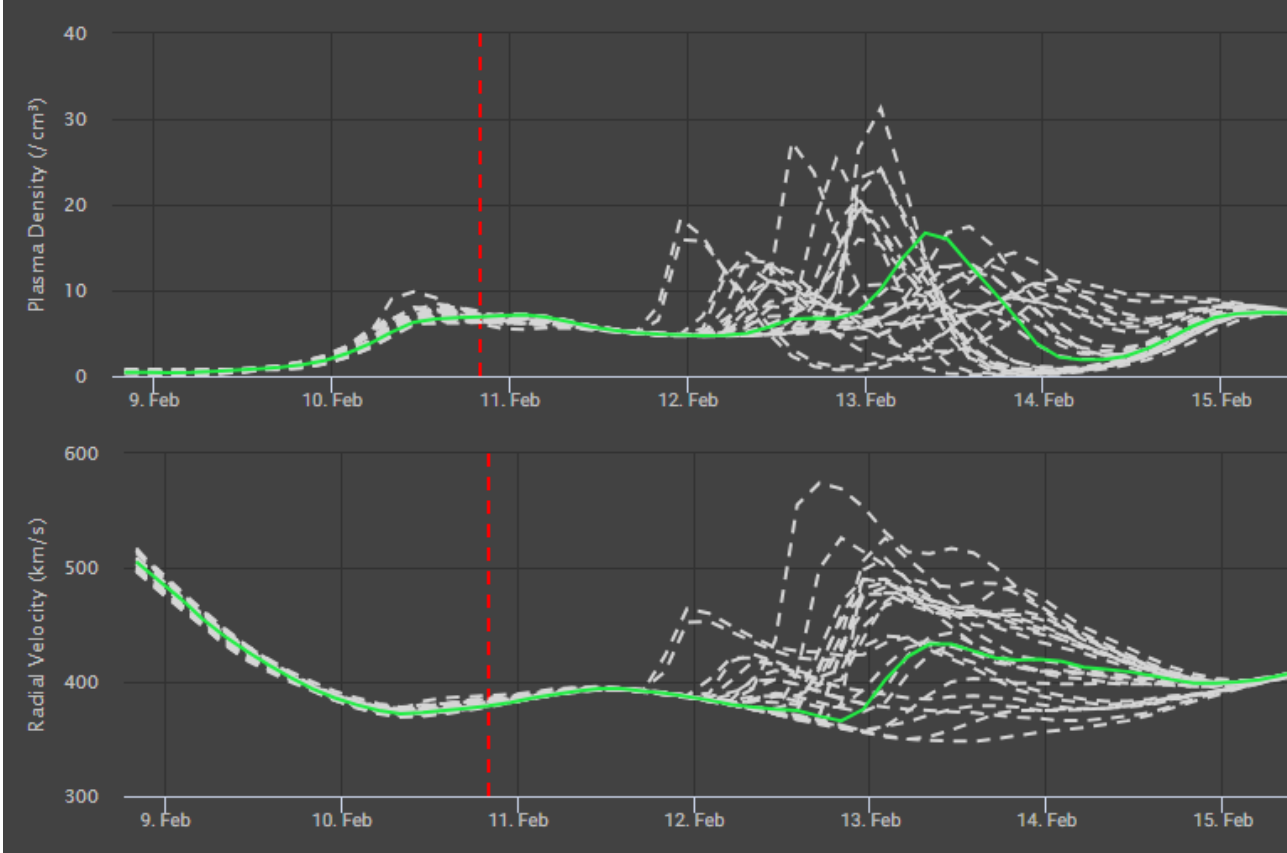


2024-02-13 00:00:00



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Enlil v2.7 | WSA v4.5 | Model Run: 2024-02-10T18Z



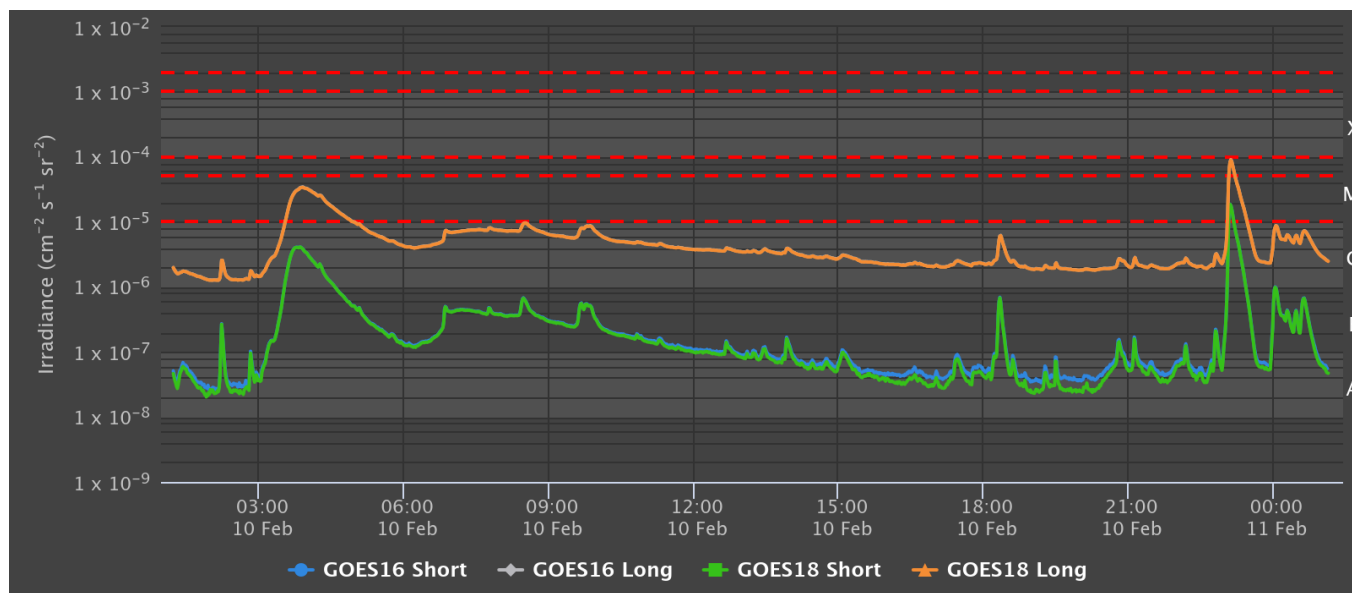
## Radio Blackouts - X-Ray Flares:

The risks of flare activity are now dominated by AR3576 near centre-disc with the passing of Ex-AR3575, although the latter does still factor into the probabilities initially due to the possibility it throws emissive ejecta high into the corona, as seen in the past 24 hours.

The daily risk of significant flares is maintained through the period with further M-class flares considered likely from AR3576, with a Slight Chance of X-class. The returning Carrington locations for several past regions are due over the eastern solar horizon in the period - the flux emanating from the first of these is now visible in AIA171 over the southeastern solar horizon, however any contribution from these regions will be assessed as and when they appear over the eastern solar horizon.

| X Ray Flares | Level               | Past 24 Hours<br>(Yes/No) | Day 1<br>(00-24 UTC) | Day 2<br>(00-24 UTC) | Day 3<br>(00-24 UTC) | Day 4<br>(00-24 UTC) |
|--------------|---------------------|---------------------------|----------------------|----------------------|----------------------|----------------------|
| Probability  |                     |                           | (%)                  | (%)                  | (%)                  | (%)                  |
| Active       | R1-R2<br>M Class    | Yes                       | 70                   | 70                   | 70                   | 70                   |
| Very Active  | R3 to R5<br>X Class | No                        | 20                   | 20                   | 20                   | 20                   |

Figure 4: GOES18 X-Ray trace



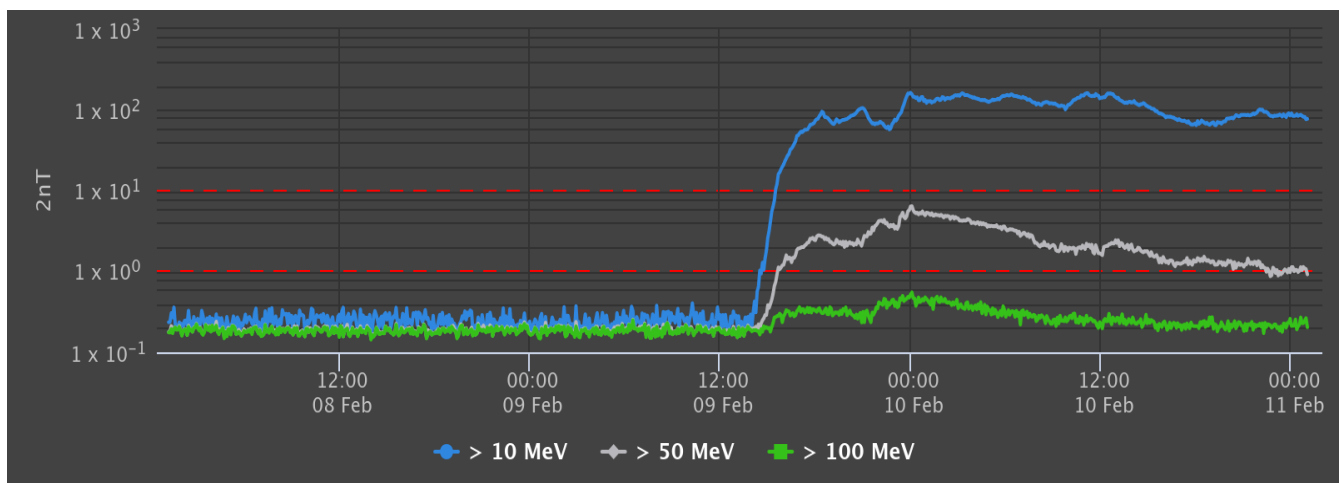
## Solar Radiation Storms - (High Energy Protons):

GOES18 high energy (greater than 10MeV) proton flux is currently at S1 levels following the enhancement from the X3.3 flare from 09 Feb, associated with Ex-AR3575. The high energy proton flux should begin to subside through the period, though likely remaining above S1 through day 1 (11 Feb), with a gradual fall to below S1 levels possibly by day 3 (13 Feb). There will likely remain an elevated potential to rise above the S1/Minor Radiation Storm level in response to any significant flares through the period, these flares increasingly likely from AR3576 as it rotates further into the western hemisphere.

| Radiation Storms            | Level<br>( $\text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1}$ ) | Past 24 Hours<br>(Yes/No) | Day 1<br>(00-24 UTC) | Day 2<br>(00-24 UTC) | Day 3<br>(00-24 UTC) | Day 4<br>(00-24 UTC) |
|-----------------------------|------------------------------------------------------------|---------------------------|----------------------|----------------------|----------------------|----------------------|
| Probability<br>(Exceedance) |                                                            |                           | (%)                  | (%)                  | (%)                  | (%)                  |
| Active                      | $\geq \text{S1}$                                           | Yes                       | 99                   | 80                   | 40                   | 30                   |
| Very Active                 | $\geq \text{S3}$<br>*                                      | No                        | 10                   | 1                    | 1                    | 1                    |

\* S3  $\geq 10 \text{ MeV} \geq 1000 \text{ pfu}$  and / or  $\geq 50 \text{ MeV} \geq 10 \text{ pfu}$ . (pfu =  $\text{cm}^{-2}\text{sr}^{-1}\text{s}^{-1}$ )

Figure 5: Proton trace for the past 3-days – remains above the S1 (10 MeV) threshold.



## High Energy Electrons Event ( $\geq 2\text{MeV}$ ):

High energy electron flux (greater than 2MeV) as observed by GOES16 is expected continue at mainly Normal Background levels, given the expected absence of significant fast wind streams and glancing incidence of any CME activity.

The associated 24-hour electron fluence is expected to remain well below the Active ( $1\text{e}8$  integrated flux) threshold, as suggested by MOSWOC REFM, although the current forecast period is likely to move away from a predictable coronal hole fast/slow pattern and more towards a threat of CMEs given AR3576's position on the disc, rendering REFM less reliable.

| GEO Electron Environment | Level ( $\text{cm}^{-2} \text{sr}^{-1} \text{day}^{-1}$ ) | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) | Day 2 (00-24 UTC) | Day 3 (00-24 UTC) | Day 4 (00-24 UTC) |
|--------------------------|-----------------------------------------------------------|------------------------|-------------------|-------------------|-------------------|-------------------|
| Probability (Exceedance) |                                                           |                        | (%)               | (%)               | (%)               | (%)               |
| Active                   | $\geq 2 \text{ MeV}$<br>$\geq 1 \times 10^8$              | No                     | 1                 | 1                 | 1                 | 1                 |
| Very Active              | $\geq 2 \text{ MeV}$<br>$\geq 1 \times 10^9$              | No                     | 1                 | 1                 | 1                 | 1                 |

Figure 6: MOSWOC REFM electron fluence.

